

Title: AN IMPROVED IMPELLER BLADE

Inventor(s): Bradbury, et al.— Express Mail Label No. EV 3200451689 US
Schulte Roth & Zabel, LLP – Todd Sicklinger, Esq.
Atty. Ref.: 861975/0270

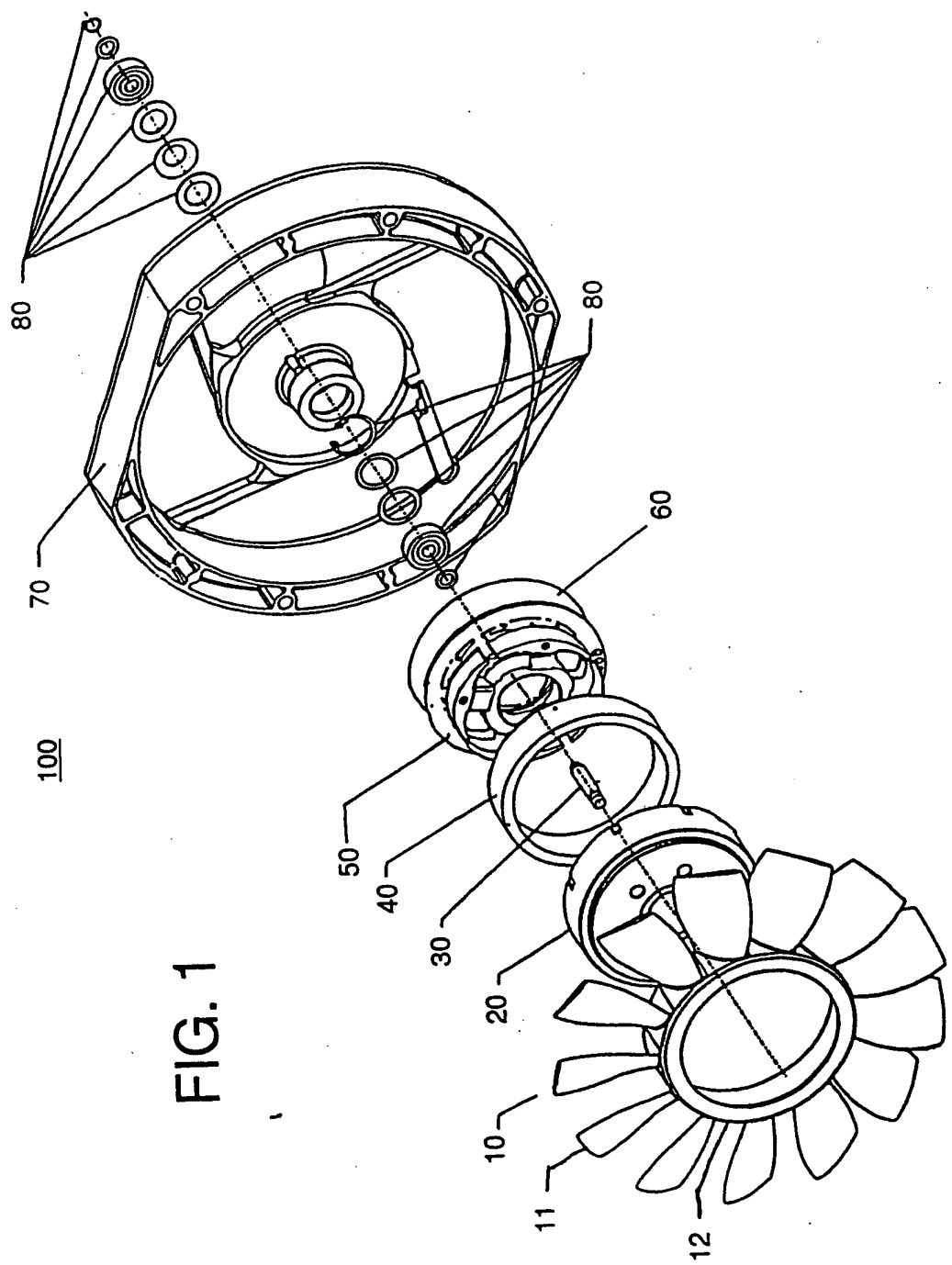


FIG. 1

100

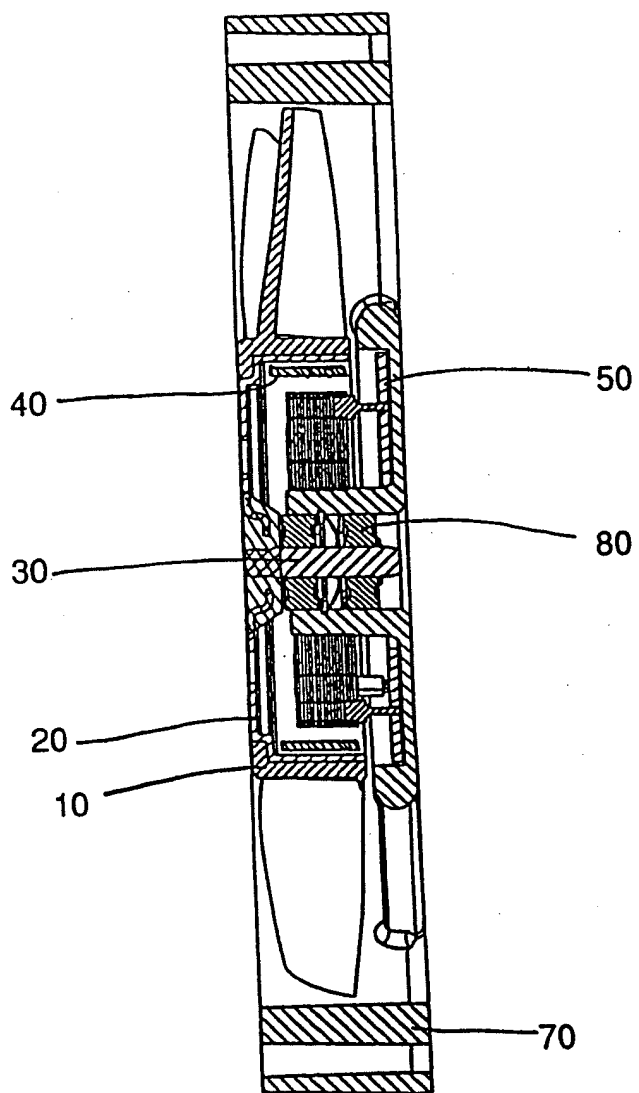


FIG. 2

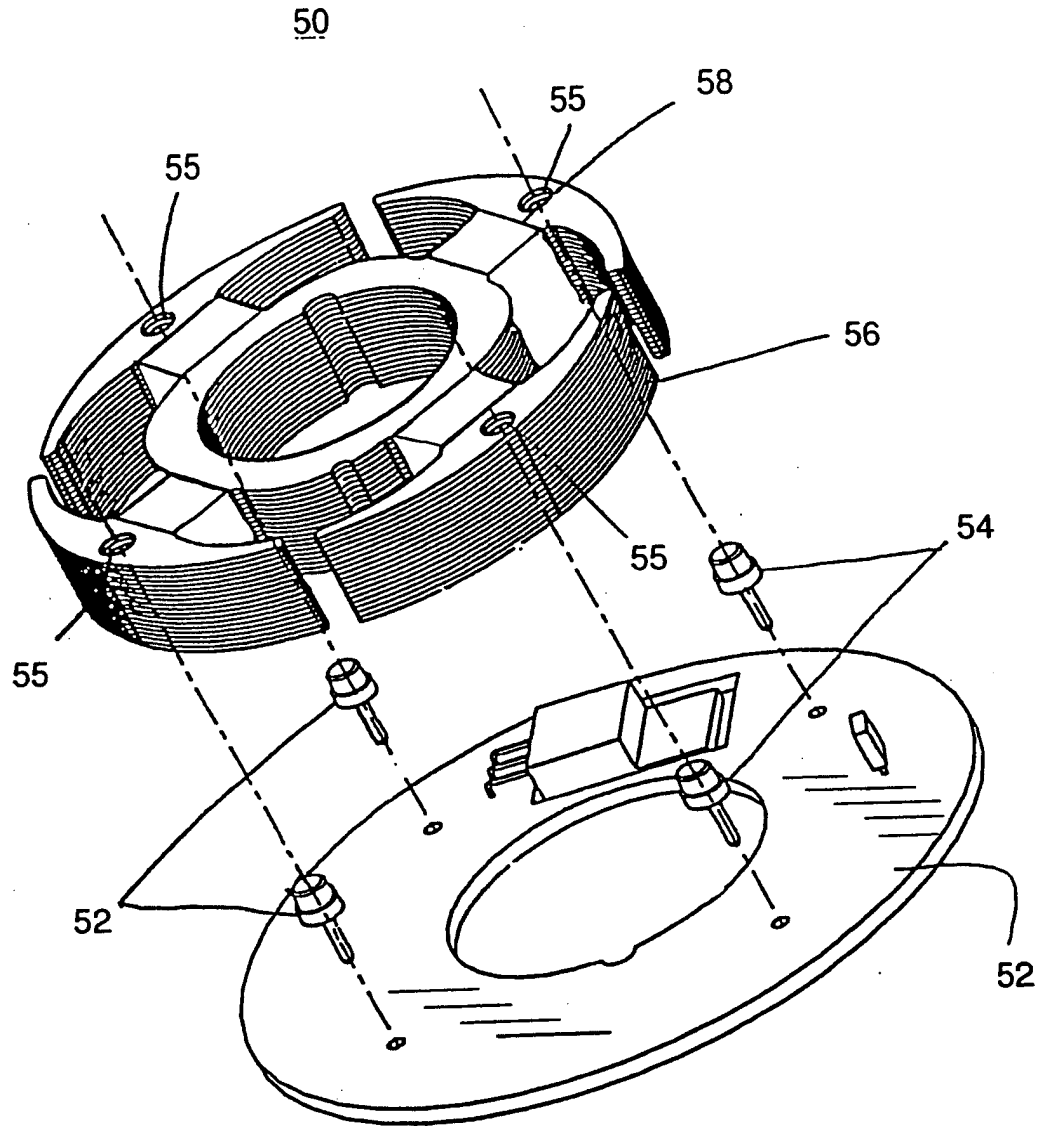


FIG. 3

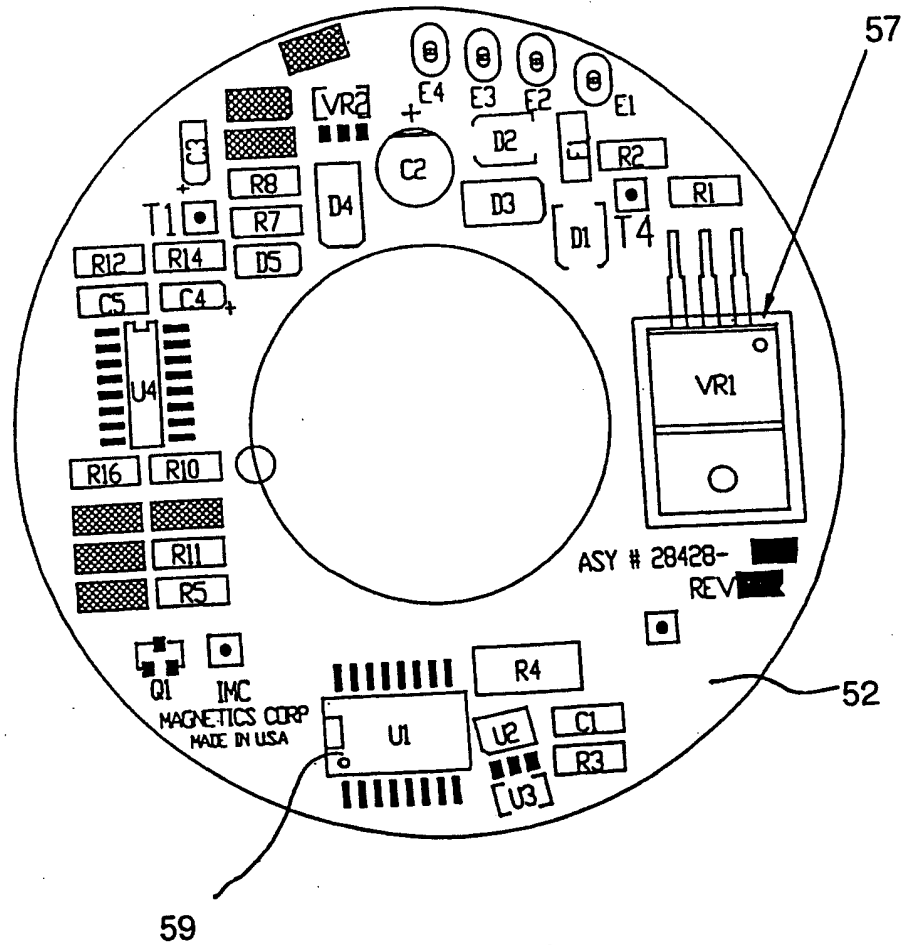


FIG. 5

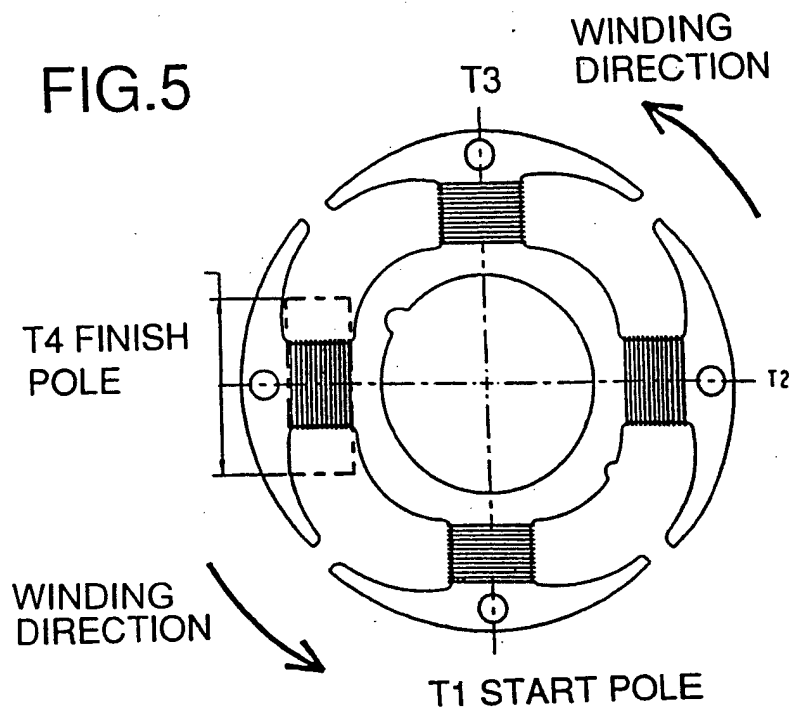
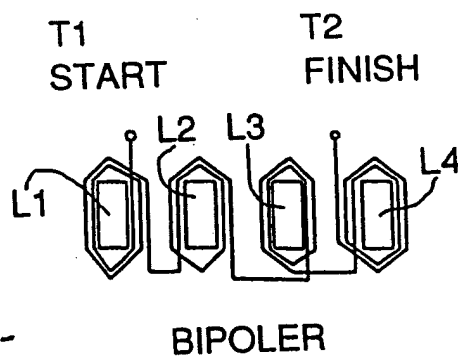


FIG. 6



Title: AN IMPROVED IMPELLER BLADE
Radbury, et al - Experimental

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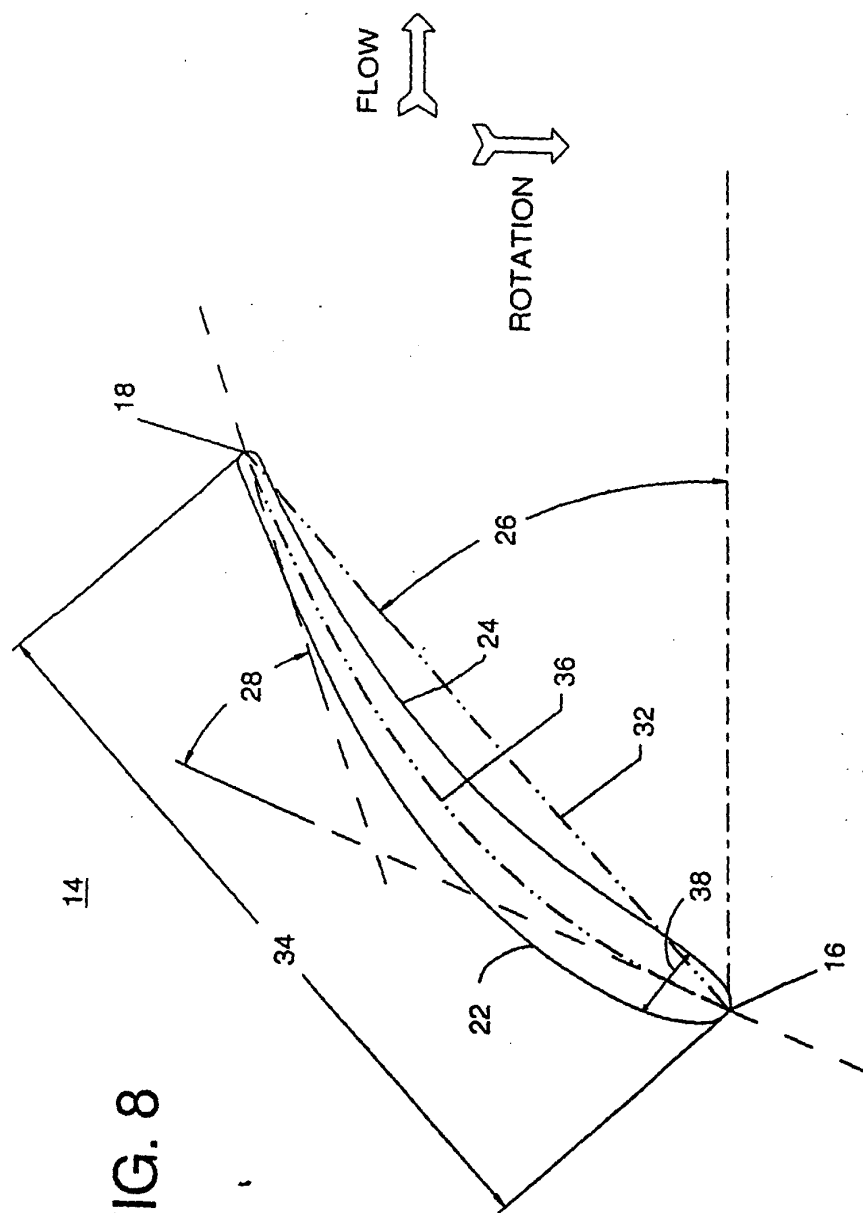


Fig. 8

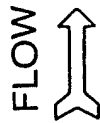


FIG. 9B

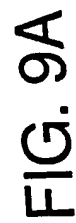


FIG. 9A

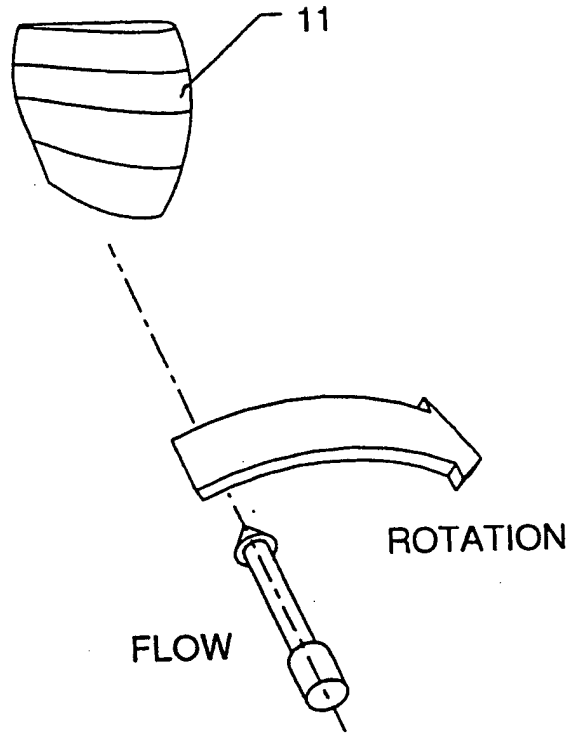


FIG. 10

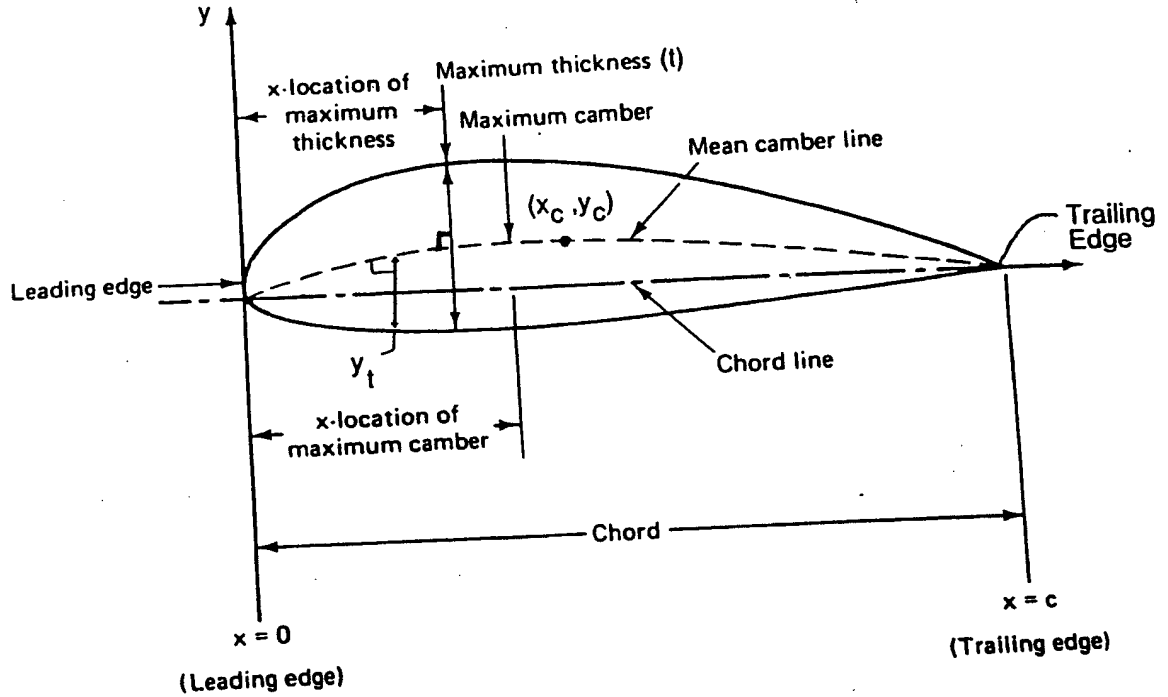


FIG. 11

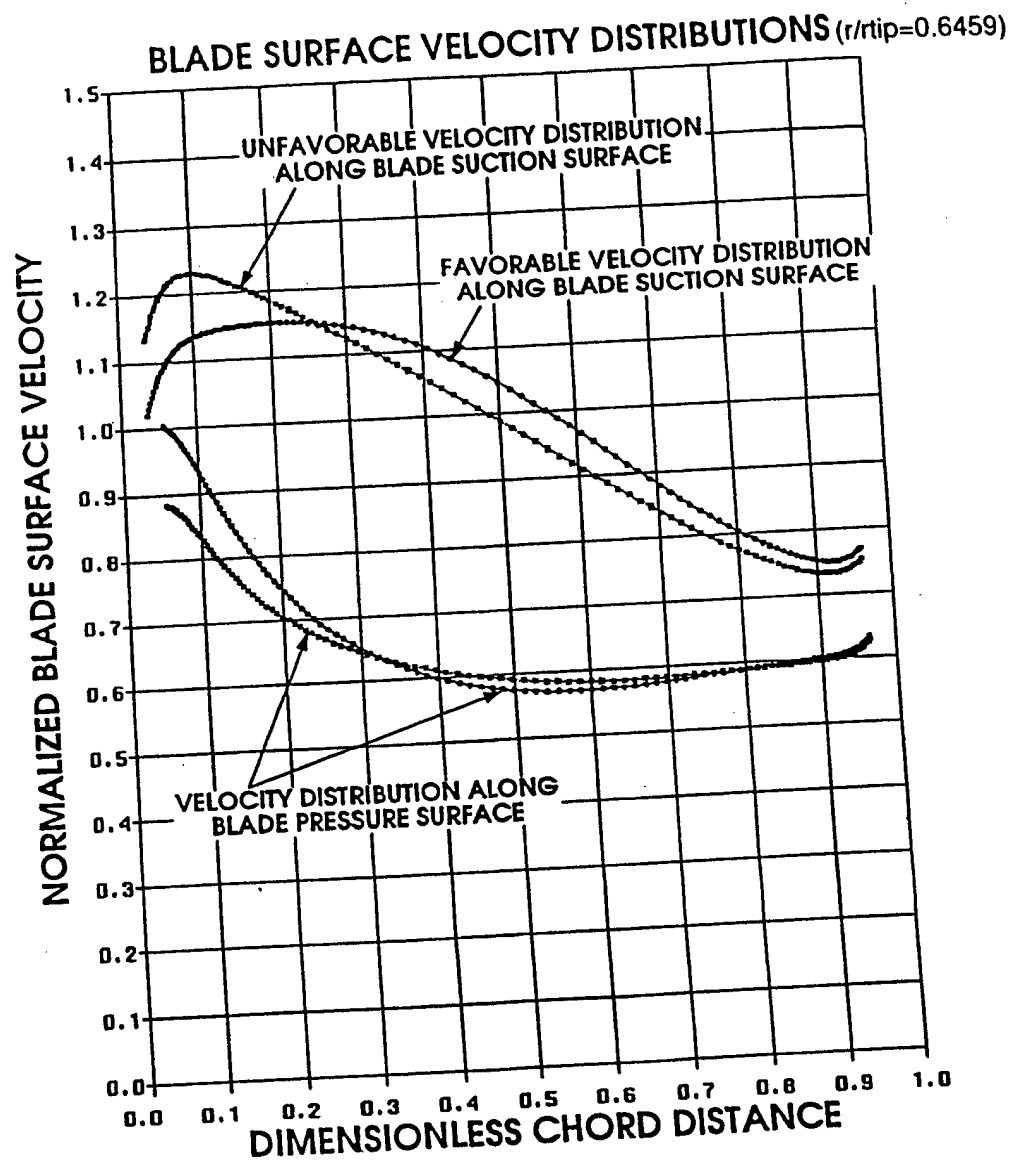


FIG. 12

NORMALIZED BEZIER CONTROL POINTS

| k | r/r _{tip} = 0.5009 | | | r/r _{tip} = 0.6459 | | |
|----|-----------------------------|----------------|----------------|-----------------------------|----------------|----------------|
| | x _k | y _k | t _k | x _k | y _k | t _k |
| 0 | 0.00 | 0.00000 | 3.66090 | 0.00 | 0.00000 | 2.96628 |
| 1 | 1.25 | 0.58007 | 5.24729 | 1.25 | 0.40469 | 4.25167 |
| 2 | 2.50 | 1.16014 | 6.46759 | 2.50 | 0.80938 | 5.24043 |
| 3 | 5.00 | 2.32029 | 8.54210 | 5.00 | 1.61876 | 6.92133 |
| 4 | 7.50 | 3.48043 | 12.08097 | 7.50 | 2.42814 | 9.78873 |
| 5 | 10.00 | 4.64057 | 12.08097 | 10.00 | 3.23751 | 9.78873 |
| 6 | 15.00 | 6.96086 | 12.08097 | 15.00 | 4.85627 | 9.78873 |
| 7 | 20.00 | 9.28114 | 12.08097 | 20.00 | 6.47503 | 9.78873 |
| 8 | 30.00 | 12.34440 | 12.08097 | 30.00 | 9.05043 | 9.78873 |
| 9 | 40.00 | 12.34440 | 10.98270 | 40.00 | 9.05043 | 8.89885 |
| 10 | 50.00 | 13.37310 | 7.80992 | 50.00 | 9.80463 | 6.32807 |
| 11 | 60.00 | 12.34440 | 7.80992 | 60.00 | 9.05043 | 6.32807 |
| 12 | 70.00 | 8.22960 | 5.73541 | 70.00 | 6.03362 | 4.64718 |
| 13 | 80.00 | 6.86226 | 3.66090 | 80.00 | 4.64103 | 2.96628 |
| 14 | 90.00 | 3.48391 | 3.29481 | 90.00 | 2.35621 | 2.66965 |
| 15 | 95.00 | 1.79474 | 3.23379 | 95.00 | 1.21381 | 2.62022 |
| 16 | 97.50 | 0.95015 | 3.14227 | 97.50 | 0.64260 | 2.54606 |
| 17 | 98.75 | 0.52786 | 3.09651 | 98.75 | 0.35700 | 2.50898 |
| 18 | 100.00 | 0.00000 | 3.05075 | 100.00 | 0.00000 | 2.47190 |

FIG.13A

NORMALIZED BEZIER CONTROL POINTS

| k | r/r _{tip} = 0.7909 | | | r/r _{tip} = 0.8954 | | |
|----|-----------------------------|----------------|----------------|-----------------------------|----------------|----------------|
| | x _k | y _k | t _k | x _k | y _k | t _k |
| 0 | 0.00 | 0.00000 | 2.66901 | 0.00 | 0.00000 | 2.71440 |
| 1 | 1.25 | 0.28327 | 3.82559 | 1.25 | 0.24026 | 3.89065 |
| 2 | 2.50 | 0.56654 | 4.71526 | 2.50 | 0.48052 | 4.79545 |
| 3 | 5.00 | 1.13309 | 6.22770 | 5.00 | 0.96103 | 6.33361 |
| 4 | 7.50 | 1.69963 | 8.80774 | 7.50 | 1.44155 | 8.95753 |
| 5 | 10.00 | 2.26618 | 8.80774 | 10.00 | 1.92207 | 8.95753 |
| 6 | 15.00 | 3.39926 | 8.80774 | 15.00 | 2.88310 | 8.95753 |
| 7 | 20.00 | 4.53235 | 8.80774 | 20.00 | 3.84414 | 8.95753 |
| 8 | 30.00 | 6.54998 | 8.80774 | 30.00 | 5.39486 | 8.95753 |
| 9 | 40.00 | 6.54998 | 8.00704 | 40.00 | 5.39486 | 8.14321 |
| 10 | 50.00 | 7.09582 | 5.69389 | 50.00 | 5.84443 | 5.79073 |
| 11 | 60.00 | 6.54998 | 5.69389 | 60.00 | 5.39486 | 5.79073 |
| 12 | 70.00 | 4.36666 | 4.18145 | 70.00 | 3.59657 | 4.25257 |
| 13 | 80.00 | 3.09061 | 2.66901 | 80.00 | 2.53886 | 2.71440 |
| 14 | 90.00 | 1.56908 | 2.40211 | 90.00 | 1.28896 | 2.44296 |
| 15 | 95.00 | 0.80831 | 2.35763 | 95.00 | 0.66401 | 2.39772 |
| 16 | 97.50 | 0.42793 | 2.29090 | 97.50 | 0.35153 | 2.32986 |
| 17 | 98.75 | 0.23774 | 2.25754 | 98.75 | 0.19530 | 2.29593 |
| 18 | 100.00 | 0.00000 | 2.22418 | 100.00 | 0.00000 | 2.26200 |

FIG.13B

NORMALIZED BEZIER CONTROL POINTS

| k | r/r _{tip} = 1.0000 | | |
|----|-----------------------------|----------------|----------------|
| | x _k | y _k | t _k |
| 0 | 0.00 | 0.00000 | 3.06144 |
| 1 | 1.25 | 0.23550 | 4.38806 |
| 2 | 2.50 | 0.47100 | 5.40854 |
| 3 | 5.00 | 0.94201 | 7.14336 |
| 4 | 7.50 | 1.41301 | 10.10275 |
| 5 | 10.00 | 1.88402 | 10.10275 |
| 6 | 15.00 | 2.82603 | 10.10275 |
| 7 | 20.00 | 3.76803 | 10.10275 |
| 8 | 30.00 | 4.93440 | 10.10275 |
| 9 | 40.00 | 4.93440 | 9.18432 |
| 10 | 50.00 | 5.34560 | 6.53107 |
| 11 | 60.00 | 4.93440 | 6.53107 |
| 12 | 70.00 | 3.28960 | 4.79626 |
| 13 | 80.00 | 2.47777 | 3.06144 |
| 14 | 90.00 | 1.25795 | 2.75530 |
| 15 | 95.00 | 0.64803 | 2.70427 |
| 16 | 97.50 | 0.34308 | 2.62774 |
| 17 | 98.75 | 0.19060 | 2.58947 |
| 18 | 100.00 | 0.00000 | 2.55120 |

FIG. 13C

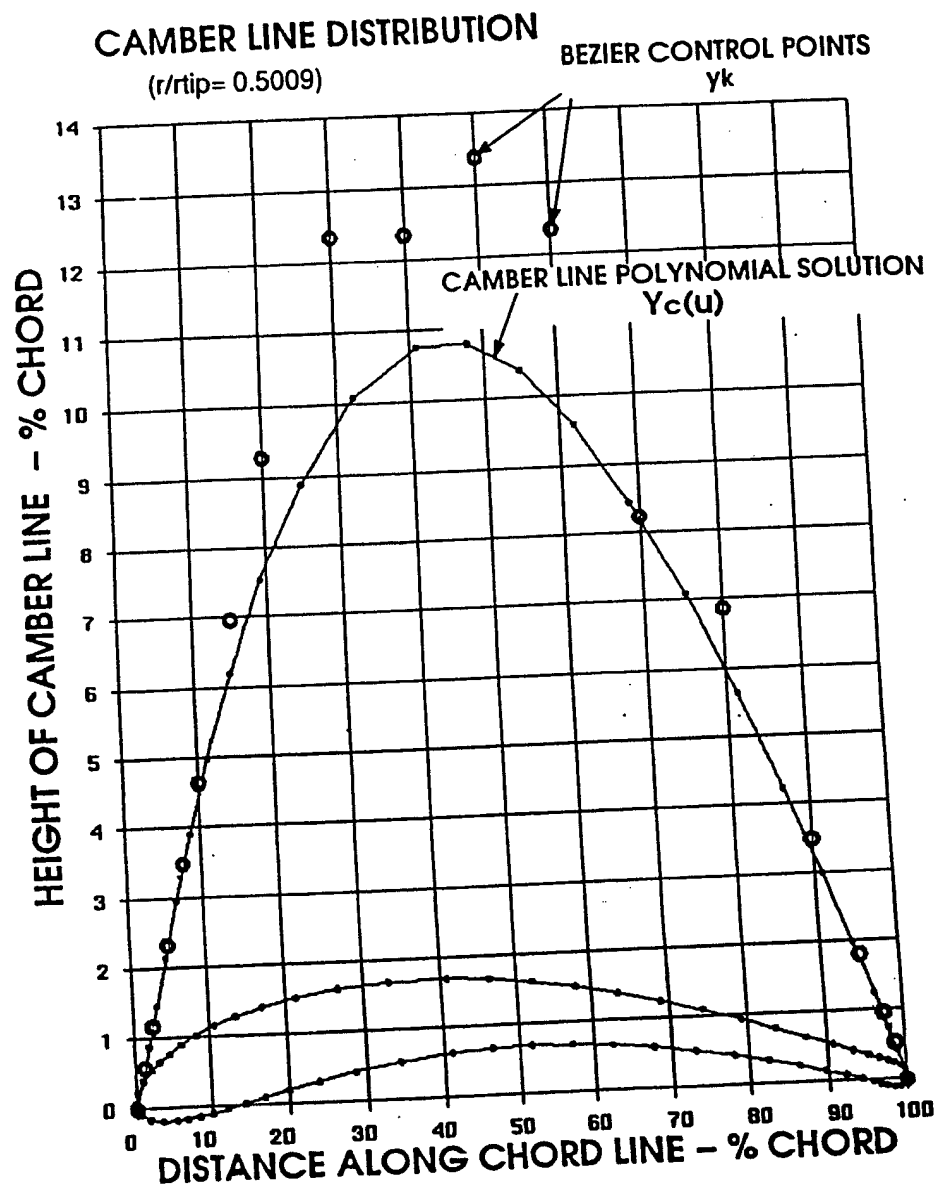


FIG. 14

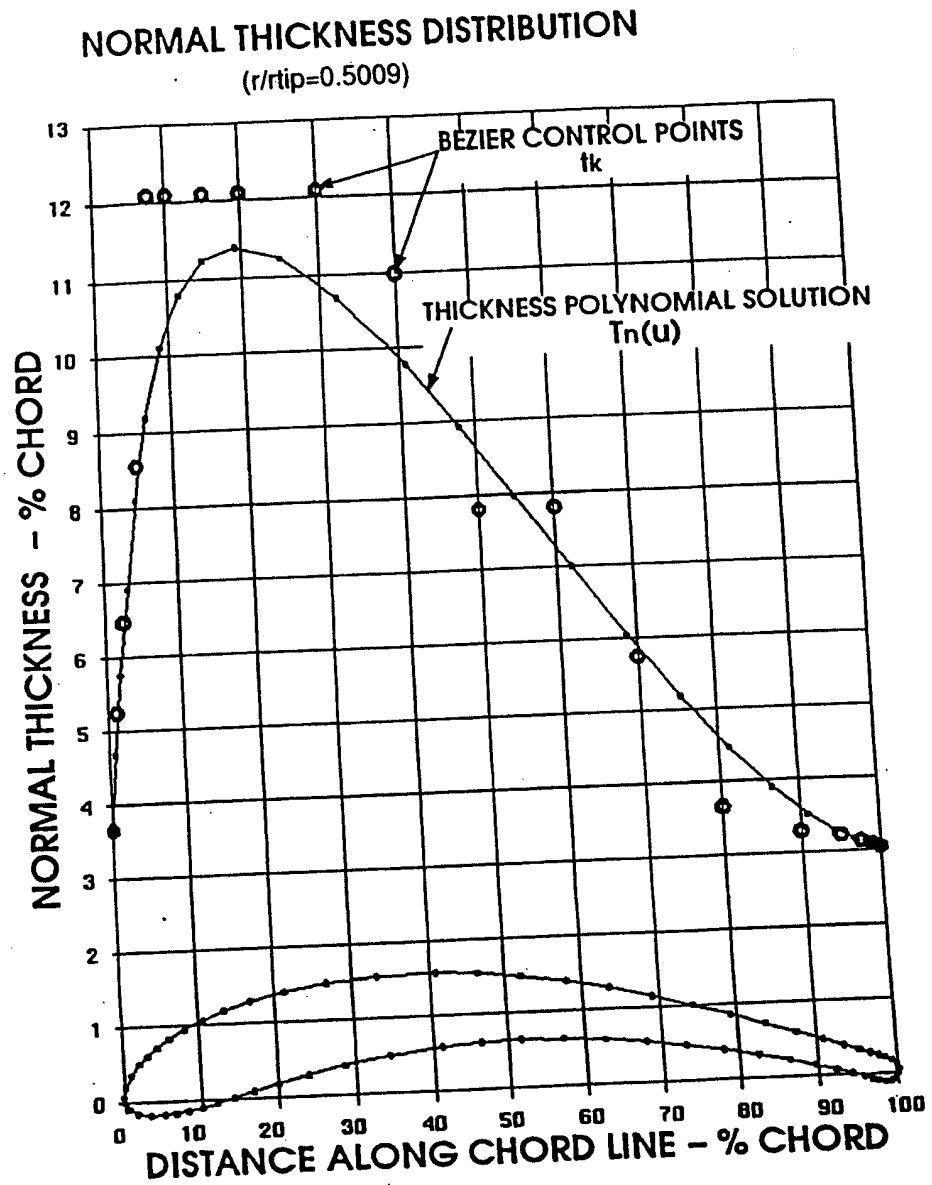


FIG. 15

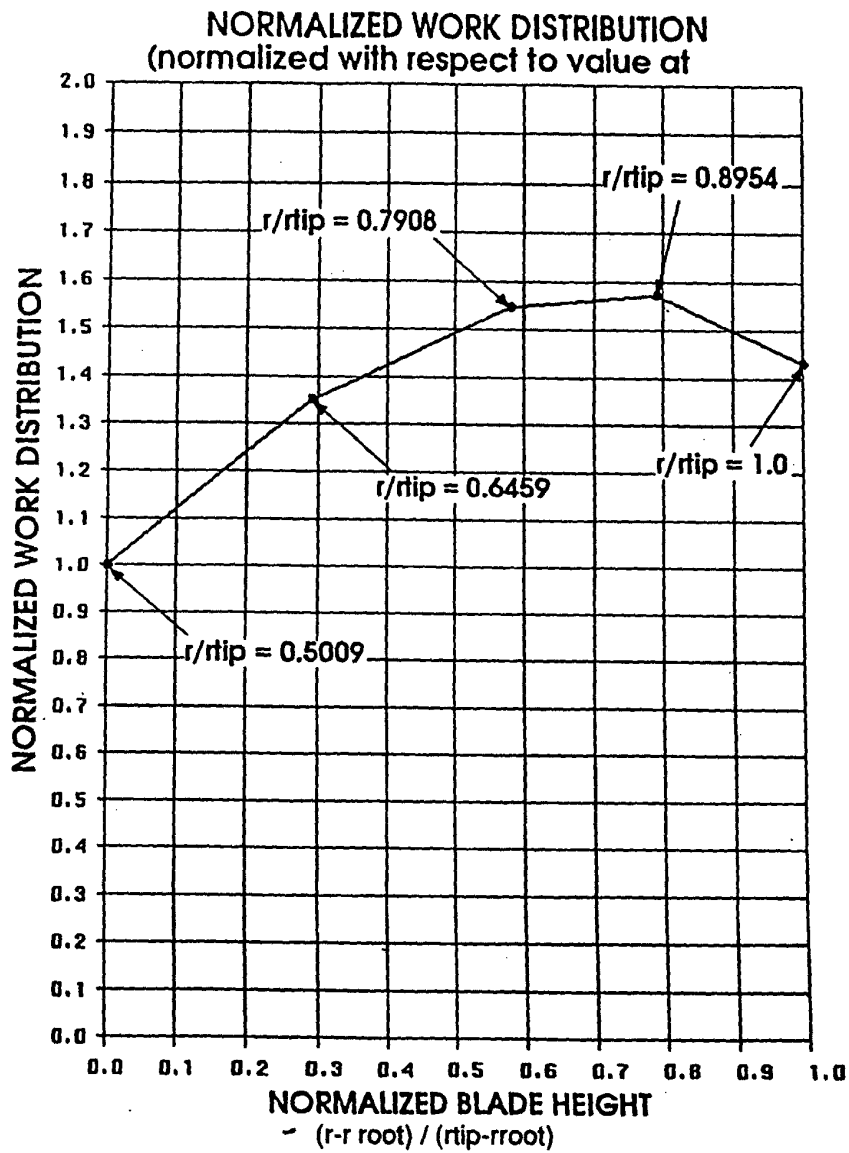


FIG. 16

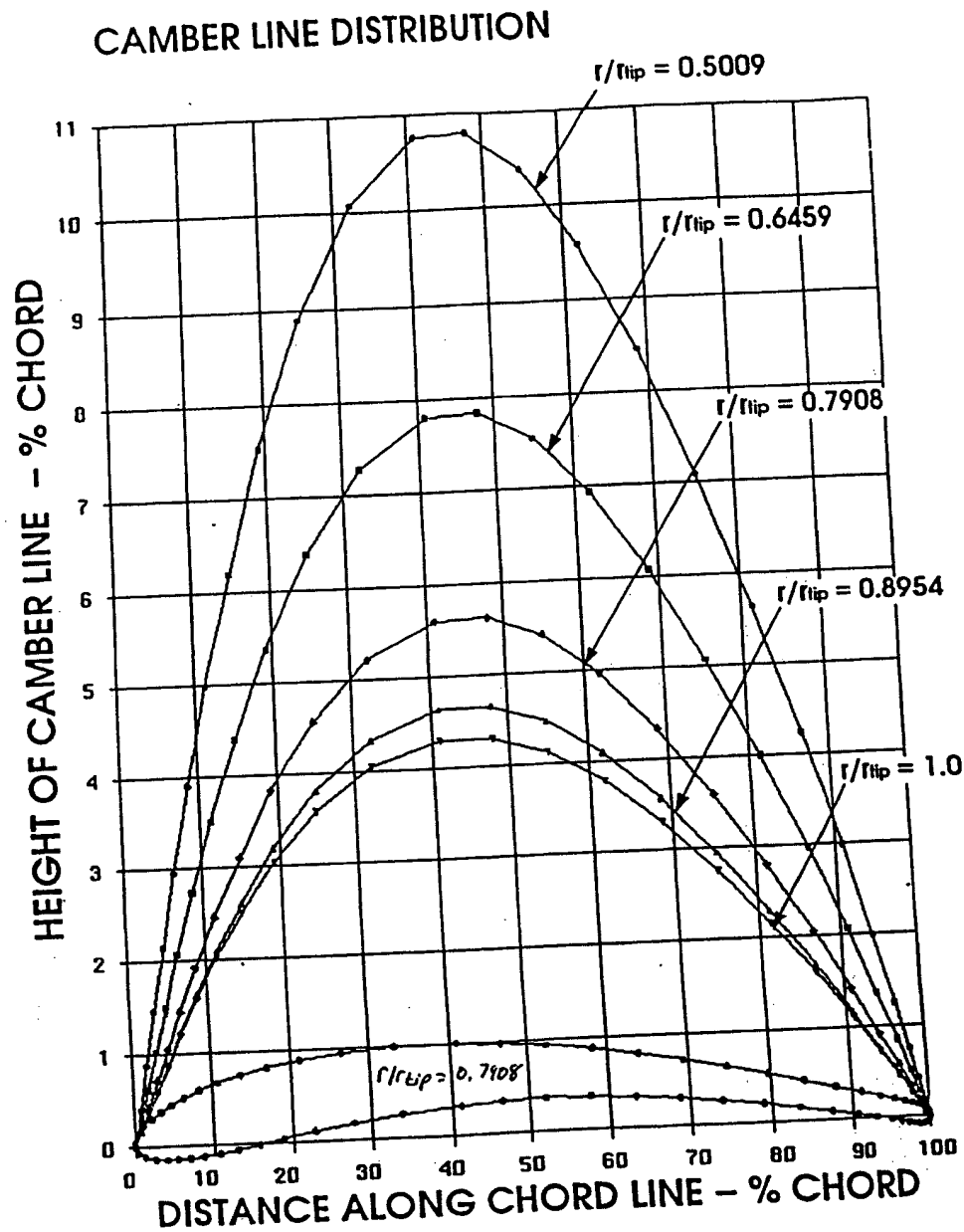


FIG. 17

NORMAL THICKNESS DISTRIBUTION

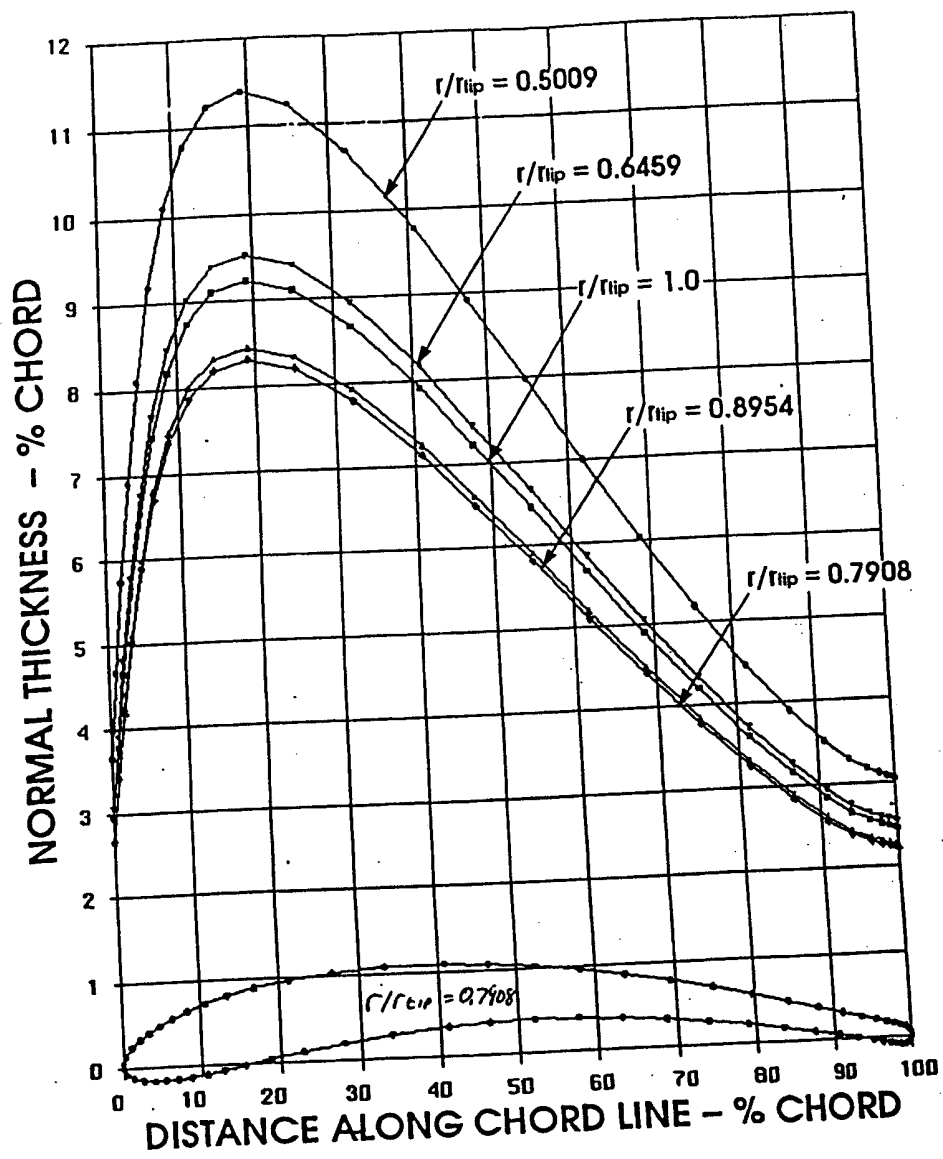


FIG. 18

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NORMALIZED BLADE PROFILES

- $r/r_{tip} = 0.5009$
- $r/r_{tip} = 0.6459$
- ◇ $r/r_{tip} = 0.7908$
- △ $r/r_{tip} = 0.8954$
- ▽ $r/r_{tip} = 1.0$

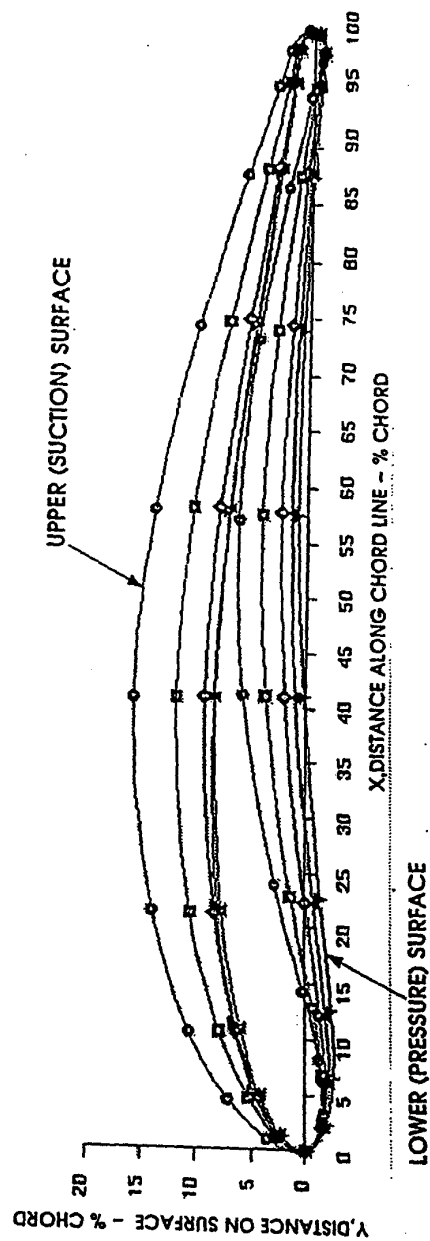


FIG. 19

| BLADE DEFINITION | ROOT | | | | TIP |
|--|--------|---------|---------|--------|--------|
| RADIUS (INCHES) | 1.4175 | 1.8278 | 2.2381 | 2.5340 | 2.8300 |
| NORMALIZED RADIUS | 0.5009 | 0.6459 | 0.7908 | 0.8954 | 1.0000 |
| CHORD LENGTH (INCHES) | 0.7785 | 0.9608 | 1.0678 | 1.0499 | 0.9309 |
| NORMALIZED CHORD | 0.8363 | 1.0321 | 1.1471 | 1.1278 | 1.0000 |
| ASPECT RATIO | 1.8144 | 1.4701 | 1.3228 | 1.3454 | 1.5173 |
| SOLIDITY | 1.1363 | 1.0876 | 0.9871 | 0.8573 | 0.6806 |
| STAGGER ANGLE (DEGREES) | 41.831 | 51.330 | 58.685 | 62.607 | 65.653 |
| CAMBER ANGLE (DEGREES) | 47.788 | 33.879 | 23.537 | 19.760 | 19.339 |
| MAXIMUM CAMBER HEIGHT (INCHES) | 0.084 | 0.076 | 0.060 | 0.049 | 0.040 |
| MAXIMUM CAMBER HEIGHT (%CHORD) | 10.823 | 7.863 | 5.652 | 4.671 | 4.320 |
| LOCATION OF MAXIMUM CAMBER (%CHORD) | 45.284 | 45.284 | 45.284 | 45.284 | 45.284 |
| MAXIMUM THICKNESS (INCHES) | 0.089 | 0.089 | 0.089 | 0.089 | 0.089 |
| MAXIMUM THICKNESS (%CHORD) | 11.392 | 9.230 | 8.305 | 8.446 | 9.526 |
| LOCATION OF MAXIMUM THICKNESS (%CHORD) | 19.174 | 19.174 | 19.174 | 19.174 | 19.174 |
| LEADING-EDGE THICKNESS (%CHORD) | 3.661 | 2.966 | 2.669 | 2.714 | 3.062 |
| TRAILING-EDGE THICKNESS (%CHORD) | 3.051 | 2.472 | 2.224 | 2.262 | 2.551 |
| CIRCUMFERENTIAL STACKING DISTANCE (INCHES) | 0.0000 | 0.1335 | 0.2141 | 0.2235 | 0.1806 |
| NORMALIZED CIRCUMFERENTIAL STACKING DISTANCE | 0.0000 | 0.7392 | 1.1855 | 1.2375 | 1.0000 |
| AXIAL STACKING DISTANCE (INCHES) | 0.0000 | -0.0419 | -0.0156 | 0.0216 | 0.0800 |
| NORMALIZED AXIAL STACKING DISTANCE | 0.0000 | -0.5238 | -0.1950 | 0.2700 | 1.0000 |

FIG. 20

NORMALIZED BLADE SURFACE COORDINATES
 $r/r_{tip} = 0.5009$

| # | XUPPER/C | YUPPER/C | XLOWER/C | YLOWER/C |
|----|----------|----------|----------|----------|
| 1 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2 | -0.00164 | 0.00733 | 0.00538 | -0.00793 |
| 3 | 0.00112 | 0.02029 | 0.01684 | -0.01404 |
| 4 | 0.00932 | 0.03584 | 0.03360 | -0.01692 |
| 5 | 0.02109 | 0.05019 | 0.05180 | -0.01640 |
| 6 | 0.03931 | 0.06661 | 0.07545 | -0.01370 |
| 7 | 0.06421 | 0.08411 | 0.10315 | -0.00822 |
| 8 | 0.09831 | 0.10227 | 0.13646 | 0.00050 |
| 9 | 0.14433 | 0.12045 | 0.17809 | 0.01242 |
| 10 | 0.20666 | 0.13769 | 0.23280 | 0.02722 |
| 11 | 0.29321 | 0.15170 | 0.30878 | 0.04402 |
| 12 | 0.40785 | 0.15637 | 0.41136 | 0.05873 |
| 13 | 0.48494 | 0.15187 | 0.48213 | 0.06348 |
| 14 | 0.56303 | 0.14173 | 0.55559 | 0.06390 |
| 15 | 0.64006 | 0.12684 | 0.62986 | 0.05993 |
| 16 | 0.71399 | 0.10868 | 0.70267 | 0.05211 |
| 17 | 0.78256 | 0.08915 | 0.77127 | 0.04156 |
| 18 | 0.84321 | 0.07028 | 0.83245 | 0.02976 |
| 19 | 0.89333 | 0.05387 | 0.88311 | 0.01831 |
| 20 | 0.93118 | 0.04111 | 0.92126 | 0.00858 |
| 21 | 0.95695 | 0.03225 | 0.94706 | 0.00135 |
| 22 | 0.97313 | 0.02657 | 0.96313 | -0.00349 |
| 23 | 0.98367 | 0.02280 | 0.97349 | -0.00677 |
| 24 | 0.99251 | 0.01884 | 0.98231 | -0.00908 |
| 25 | 0.99912 | 0.01295 | 0.99065 | -0.00883 |
| 26 | 1.00154 | 0.00617 | 0.99676 | -0.00546 |
| 27 | 1.00000 | 0.00000 | 1.00000 | 0.00000 |

FIG. 21A

NORMALIZED BLADE SURFACE COORDINATES
 $r/r_{tip} = 0.6459$

| # | X _{UPPER/C} | Y _{UPPER/C} | X _{LOWER/C} | Y _{LOWER/C} |
|----|----------------------|----------------------|----------------------|----------------------|
| 1 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2 | -0.00057 | 0.00593 | 0.00353 | -0.00679 |
| 3 | 0.00305 | 0.01558 | 0.01204 | -0.01235 |
| 4 | 0.01137 | 0.02663 | 0.02502 | -0.01565 |
| 5 | 0.02239 | 0.03650 | 0.03950 | -0.01647 |
| 6 | 0.04094 | 0.04910 | 0.06167 | -0.01599 |
| 7 | 0.06557 | 0.06248 | 0.08862 | -0.01328 |
| 8 | 0.09882 | 0.07623 | 0.12200 | -0.00765 |
| 9 | 0.14379 | 0.08999 | 0.16473 | 0.00103 |
| 10 | 0.20537 | 0.10319 | 0.22185 | 0.01256 |
| 11 | 0.29210 | 0.11407 | 0.30204 | 0.02621 |
| 12 | 0.40847 | 0.11762 | 0.41074 | 0.03848 |
| 13 | 0.48605 | 0.11394 | 0.48434 | 0.04248 |
| 14 | 0.56498 | 0.10580 | 0.56036 | 0.04300 |
| 15 | 0.64310 | 0.09394 | 0.63677 | 0.04002 |
| 16 | 0.71816 | 0.07960 | 0.71120 | 0.03406 |
| 17 | 0.78765 | 0.06441 | 0.78079 | 0.02610 |
| 18 | 0.84872 | 0.05007 | 0.84229 | 0.01738 |
| 19 | 0.89859 | 0.03800 | 0.89258 | 0.00916 |
| 20 | 0.93558 | 0.02899 | 0.92982 | 0.00240 |
| 21 | 0.96021 | 0.02299 | 0.95452 | -0.00245 |
| 22 | 0.97534 | 0.01928 | 0.96961 | -0.00560 |
| 23 | 0.98497 | 0.01688 | 0.97912 | -0.00767 |
| 24 | 0.99235 | 0.01445 | 0.98650 | -0.00886 |
| 25 | 0.99813 | 0.01031 | 0.99327 | -0.00797 |
| 26 | 1.00065 | 0.00511 | 0.99791 | -0.00470 |
| 27 | 1.00000 | 0.00000 | 1.00000 | 0.00000 |

FIG. 21B

NORMALIZED BLADE SURFACE COORDINATES
 $r/r_{tip} = 0.7908$

| # | XUPPER/C | YUPPER/C | XLOWER/C | YLOWER/C |
|----|----------|----------|----------|----------|
| 1 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2 | -0.00002 | 0.00532 | 0.00261 | -0.00633 |
| 3 | 0.00405 | 0.01350 | 0.00976 | -0.01180 |
| 4 | 0.01246 | 0.02246 | 0.02106 | -0.01554 |
| 5 | 0.02316 | 0.03013 | 0.03388 | -0.01720 |
| 6 | 0.04207 | 0.04036 | 0.05523 | -0.01835 |
| 7 | 0.06677 | 0.05104 | 0.08164 | -0.01775 |
| 8 | 0.09972 | 0.06171 | 0.11492 | -0.01464 |
| 9 | 0.14420 | 0.07212 | 0.15811 | -0.00877 |
| 10 | 0.20533 | 0.08191 | 0.21639 | -0.00027 |
| 11 | 0.29193 | 0.08973 | 0.29865 | 0.01036 |
| 12 | 0.40884 | 0.09169 | 0.41037 | 0.02047 |
| 13 | 0.48655 | 0.08831 | 0.48539 | 0.02408 |
| 14 | 0.56581 | 0.08151 | 0.56268 | 0.02509 |
| 15 | 0.64440 | 0.07187 | 0.64012 | 0.02345 |
| 16 | 0.71997 | 0.06045 | 0.71531 | 0.01955 |
| 17 | 0.78988 | 0.04857 | 0.78535 | 0.01415 |
| 18 | 0.85113 | 0.03762 | 0.84695 | 0.00821 |
| 19 | 0.90087 | 0.02868 | 0.89702 | 0.00265 |
| 20 | 0.93743 | 0.02222 | 0.93380 | -0.00185 |
| 21 | 0.96150 | 0.01808 | 0.95797 | -0.00502 |
| 22 | 0.97614 | 0.01559 | 0.97261 | -0.00705 |
| 23 | 0.98535 | 0.01402 | 0.98176 | -0.00836 |
| 24 | 0.99210 | 0.01236 | 0.98851 | -0.00894 |
| 25 | 0.99754 | 0.00909 | 0.99456 | -0.00766 |
| 26 | 1.00018 | 0.00463 | 0.99850 | -0.00438 |
| 27 | 1.00000 | 0.00000 | 1.00000 | 0.00000 |

FIG. 21C

NORMALIZED BLADE SURFACE COORDINATES
 $r/r_{tip} = 0.8954$

| # | XUPPER/C | YUPPER/C | XLOWER/C | YLOWER/C |
|----|----------|----------|----------|----------|
| 1 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2 | 0.00015 | 0.00543 | 0.00245 | -0.00654 |
| 3 | 0.00456 | 0.01368 | 0.00954 | -0.01240 |
| 4 | 0.01340 | 0.02259 | 0.02092 | -0.01665 |
| 5 | 0.02452 | 0.03007 | 0.03391 | -0.01884 |
| 6 | 0.04367 | 0.03972 | 0.05514 | -0.02078 |
| 7 | 0.06861 | 0.04958 | 0.08145 | -0.02110 |
| 8 | 0.10173 | 0.05913 | 0.11469 | -0.01911 |
| 9 | 0.14620 | 0.06809 | 0.15790 | -0.01461 |
| 10 | 0.20706 | 0.07612 | 0.21624 | -0.00770 |
| 11 | 0.29306 | 0.08204 | 0.29855 | 0.00125 |
| 12 | 0.40901 | 0.08262 | 0.41020 | 0.01019 |
| 13 | 0.48630 | 0.07908 | 0.48527 | 0.01374 |
| 14 | 0.56519 | 0.07269 | 0.56254 | 0.01525 |
| 15 | 0.64350 | 0.06399 | 0.63990 | 0.01463 |
| 16 | 0.71889 | 0.05388 | 0.71497 | 0.01213 |
| 17 | 0.78871 | 0.04349 | 0.78489 | 0.00831 |
| 18 | 0.84996 | 0.03399 | 0.84643 | 0.00391 |
| 19 | 0.89976 | 0.02628 | 0.89652 | -0.00033 |
| 20 | 0.93644 | 0.02076 | 0.93340 | -0.00384 |
| 21 | 0.96066 | 0.01724 | 0.95769 | -0.00637 |
| 22 | 0.97541 | 0.01513 | 0.97245 | -0.00799 |
| 23 | 0.98470 | 0.01380 | 0.98169 | -0.00906 |
| 24 | 0.99160 | 0.01232 | 0.98859 | -0.00945 |
| 25 | 0.99722 | 0.00916 | 0.99472 | -0.00796 |
| 26 | 1.00003 | 0.00471 | 0.99862 | -0.00450 |
| 27 | 1.00000 | 0.00000 | 1.00000 | 0.00000 |

FIG. 21D

NORMALIZED BLADE SURFACE COORDINATES
 $r/r_{tip} = 1.0000$

| # | XUPPER/C | YUPPER/C | XLOWER/C | YLOWER/C |
|----|----------|----------|----------|----------|
| 1 | 0.00000 | 0.00000 | 0.00000 | 0.00000 |
| 2 | 0.00018 | 0.00621 | 0.00274 | -0.00746 |
| 3 | 0.00514 | 0.01586 | 0.01079 | -0.01447 |
| 4 | 0.01507 | 0.02637 | 0.02371 | -0.01981 |
| 5 | 0.02757 | 0.03517 | 0.03844 | -0.02274 |
| 6 | 0.04710 | 0.04531 | 0.06005 | -0.02523 |
| 7 | 0.07255 | 0.05535 | 0.08658 | -0.02599 |
| 8 | 0.10619 | 0.06474 | 0.11987 | -0.02446 |
| 9 | 0.15092 | 0.07313 | 0.16285 | -0.02056 |
| 10 | 0.21140 | 0.08015 | 0.22046 | -0.01444 |
| 11 | 0.29594 | 0.08465 | 0.30118 | -0.00635 |
| 12 | 0.40909 | 0.08385 | 0.41012 | 0.00215 |
| 13 | 0.48526 | 0.07979 | 0.48413 | 0.00598 |
| 14 | 0.56302 | 0.07320 | 0.56031 | 0.00815 |
| 15 | 0.64027 | 0.06461 | 0.63663 | 0.00852 |
| 16 | 0.71478 | 0.05481 | 0.71079 | 0.00722 |
| 17 | 0.78401 | 0.04481 | 0.78008 | 0.00461 |
| 18 | 0.84506 | 0.03563 | 0.84138 | 0.00125 |
| 19 | 0.89512 | 0.02811 | 0.89170 | -0.00226 |
| 20 | 0.93243 | 0.02263 | 0.92917 | -0.00536 |
| 21 | 0.95741 | 0.01907 | 0.95420 | -0.00771 |
| 22 | 0.97283 | 0.01690 | 0.96961 | -0.00928 |
| 23 | 0.98268 | 0.01552 | 0.97940 | -0.01035 |
| 24 | 0.99047 | 0.01387 | 0.98718 | -0.01073 |
| 25 | 0.99682 | 0.01033 | 0.99408 | -0.00901 |
| 26 | 1.00001 | 0.00531 | 0.99847 | -0.00508 |
| 27 | 1.00000 | 0.00000 | 1.00000 | 0.00000 |

FIG. 21E